e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2023; 15(12); 718-723

Original Research Article

An Observational Study to Identify and Treat Intraoperative Injuries to Prevent Postoperative Neurological Deficits in Cervical Spondylotic Myelopathy (CSM): A Retrospective Study

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Received: 05-08-2023 Revised: 20-09-2023 / Accepted: 21-12-2023
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Conflict of interest: Nil

Abstract

Aim: The aim of the present study was to need to identify and treat intraoperative injuries to prevent postoperative neurological deficits in cervical spondylotic myelopathy (CSM).

Methods: The present study was conducted at department of Neurosurgery, Kashi Neuron Multispeciality Hospital, Ramnagar, Varanasi UP, India. A retrospective analysis of patients who underwent surgical fusion for CSM and IONM was performed. 50 patients showed an IONM change

Results: A total of 312 patients who had a diagnosis of degenerative myelopathy and whose case involved neuromonitoring were identified; 167 were excluded for various reasons, 50 patients showed an IONM change and 95 showed no IONM change. The mean age was 57.3 ± 15.3 and 52% were females. 96% had degenerative pathology of myelopathy. According to Nurick grade, 50% were in grade 1. Among the 50 patients with neuromonitoring changes, 4 patients showed postoperative neurological deficits. For the 90 patients without IONM changes, 5 patients showed some postoperative deficit that, although mostly mild, persisted up to last follow-up. Sensitivity of 43.87%, specificity of 69.52%, positive predictive value of 8.16%, and negative predictive value of 96.52% were identified for IONM in predicting postoperative neurological changes.

Conclusion: Our study showed that IONM was efficacious as a surgical adjunct but showed limited accuracy in predicting postoperative outcome in contrast to some previous studies. Moreover, we describe how a standardized multidisciplinary collaboration using the best available evidence may serve as the most effective method to optimize patient care in light of the limitations and controversies of IONM.

Keywords: cervical spondylotic myelopathy, degenerative cervical myelopathy, electromyography, intraoperative neuromonitoring

Introduction

Cervical compressive myelopathy (CCM) is one of the most commonly acquired cause of spinal cord dysfunction [1] and surgery is usually the treatment of choice for those patients. It is important to assess cervical cord function in patients with CCM during surgical treatment. Over the past decades, the majority of studies are concerning the application of intraoperative transcranial motor evoked potential (MEP) to detect impending spinal cord damage, early warning the operating team to take action to avoid injury in cervical spine surgery. [2-5]

Intraoperative neurophysiological monitoring (IONM) is a rapidly advancing field, and neurophysiological monitoring is becoming prevalent in spinal surgery. [6] Although almost universally employed during spinal deformity surgery, the indications in "lower risk" decompressive procedures are more controversial. [7] The sensitivity of combined-modality monitoring may approach 100%, although sensitivities as low as 43% have been reported. [8] Somatosensory evoked potentials, although advantageous because they can be monitored continuously, rely on signal averaging over time, and decreases may significantly lag behind transcranial MEP changes. Monitoring of MEPs may provide earlier detection of neurological injury and is associated with high sensitivity. [3] However, MEPs cannot be monitored continuously, may induce patient movement, and are negatively affected by inhaled anesthetic agents. [3] Some argue against the use of IONM in cervical decompression altogether. [7] Few studies have focused on the use of IONM in decompressive surgery for myelopathy. [9]

Although commonly used, the efficacy of intraoperative neuromonitoring (IONM) during anterior cervical decompression and fusion has

remained controversial. One report showed a reduction of the neurological complications with anterior cervical decompression and fusion procedures with the use of IONM, [10] but other studies did not find any reduction in neurological complications. [11-13] One possible explanation for the conflicting results is the differences in the extent of surgery (single vs. multilevel procedure). The risk of neurological complications during multilevel procedures is greater owing to the more complicated preoperative status of the patient and the longer procedure time required. [14] IONM might be more effective for multilevel procedures in which the risk is greater. The pathological entity being treated can also change the efficacy of IONM. Studies of patients with degenerative diseases, fractures [15], tumors [16] and deformities8 who had undergone surgery with IONM reported different sensitivities, specificities, predictive values, and outcomes.

The aim of the present study was to need to identify and treat intraoperative injuries to prevent postoperative neurological deficits in cervical spondylotic myelopathy (CSM).

Materials and Methods

The present study was conducted at department of Neurosurgery, Kashi Neuron Multispeciality Hospital, Ramnagar ,Varanasi UP, India for one year and a retrospective analysis of patients who underwent surgical fusion for CSM and IONM was performed. A total of 312 patients who had a diagnosis of degenerative myelopathy and whose case involved neuromonitoring were identified; 167 were excluded for various reasons, 50 patients showed an IONM change and 95 showed no IONM change.

Patients were included if they were at least 18 years old, underwent anterior or posterior cervical fusion during which IONM was used, had a preoperative diagnosis of CSM, and had complete preoperative and postoperative neurological examination information. Patients with traumatic spinal cord injury or isolated thoracic myelopathy were excluded.

Patient Variables

Patients underwent standardized preoperative and intraoperative management during treatment via use of a multidisciplinary checklist. Various clinical variables were analyzed. Nurick classifications of myelopathy were analyzed (grade 0: roots only or normal; grade 1: signs of cord compression, normal gait; grade 2: gait difficulty but fully employed; grade 3: gait difficulty prevents employment, walks unassisted; grade 4: unable to walk without assistance; grade 5: wheelchair- or bedbound). [17]

Neuromonitoring Setup and Thresholds

IONM was performed in all patients by using SSEPs, tcMEPs, and spontaneous EMG activity of the nerve roots using Cascade Elite Pro equipment (Cadwell, Kennewick, Washington, United States). SSEPs were performed after bilateral independent median and posterior tibial nerve stimulation through subdermal needles. Stimulation of the ulnar nerve was performed when C8-T1 nerve roots were thought to be at risk. Supramaximal and constant current stimulation was performed to elicit a visible muscle twitch in all extremities. Recording was performed through subdermal needles placed according to the international 10 to 20 classification system with two cortical channels (C3/4 contralateral-midfrontal [MF] and C3/4 contralateral-C3/4 ipsilateral for upper extremities and Cz- MF and C3/4 contralateral-C3/4 ipsilateral for lower extremities), one subcortical channel (ipsilateral mastoid- MF for both upper and lower extremities), and ipsilateral Erb-contralateral Erb for peripheral potentials. Recording filters were a 30-Hz, low-frequency filter, and a 1000-Hz, high-frequency filter.

tcMEPs were performed through corkscrew needle electrodes positioned at M3-M4, or alternatively at M1-M2 when there was significant movement associated with stimulation with the former montage. A bite block was used in all cases. The most commonly used stimulation parameters for high-frequency pulse train stimulation were interstimulus interval of 2 milliseconds, train of 6 stimuli, pulse width of 75 μsec, and a stimulation intensity varying between 80 and 400 V that would elicit a minimum of 30-μV tcMEP response from all sampled muscles on the contralateral side with acceptable patient movement. Our muscle sampling protocol involves trapezius, deltoid, biceps, triceps, extensor digitorum communis, abductor pollicis brevis, and abductor hallucis as the most commonly sampled muscles in neuromonitoring of cervical spine procedures. tcMEPs were performed as requested and allowed by the surgeon. All traces were automatically stored. Each recording trace included tcMEP responses from all monitored muscles with both cathodal and anodal stimulation. Spontaneous EMG activity was also monitored in all sampled muscles.

The criteria for noting change were defined by the American Clinical Neurophysiology Society guidelines. [18] For SSEPs, 50% amplitude decline or more than 10% latency increase of the N20 waveform was considered as a critical change. For tcMEPs, 80% amplitude decrease was considered a significant change by default when accompanied by change in morphology from polyphasic to mono- or biphasic waveform or failure to improve despite an at least 100-V voltage increase. Occasionally, when baseline MEPs were impaired, or there was significant tuctuation because of change in

anesthetic regimen, or neuromuscular blocking agents were used, then an all-or-none criterion was used. Rarely, when there was an isolated 50% tcMEP amplitude decrease from the deltoid muscle correlating with the critical portion of surgery, then the surgeon was advised of these findings.

All interpretation was performed within the context of and considering changes in mean arterial pressure (MAP), anesthetics used, and administration timing of neuromuscular blocking agents. Baseline recordings were performed after induction of anesthesia. Baselines were obtained in supine position when there was vertebral column instability and a planned posterior approach to assess for any positioning-related compromise. Total intravenous anesthesia was used in most procedures. IONM changes were considered transient when final evoked potentials returned to baseline recordings.

Intraoperative and Postoperative Care

Several standardized measures were used at our institution during the treatment of patients with CSM. All patients routinely underwent placement of an arterial line and maintenance of MAPs more than 85 mm Hg for the duration of the case. Normothermia was targeted for all patients via Bair Hugger, and confirmation of reversal of neuromuscular blockade by train of four stimuli was achieved prior to IONM. Patients with IONM changes thought to be due to surgery were placed in an intensive care setting postoperatively for close monitoring for a minimum of 24 hours. Intravenous propofol and remifentanil along with low-dose inhalational anesthetics were routinely used. A surgical timeout was initiated before surgery in the presence of the surgical, anesthesiology, and IONM teams. Baseline potentials were obtained before any positioning, once further after positioning was acquired, and then throughout the case. After IONM changes were detected, there was collaborative troubleshooting by the surgeon, anesthesiologist, and IONM team on every case. The initial goals after IONM changes were identified were to raise MAPs if necessary, modify patient positioning or instrumentation if possible, and identify any other potentially reversible steps. The cases of patients with postoperative deficits were reviewed by the surgical and IONM teams jointly as part of a surgical debriefing. All myelopathic patients routinely underwent evaluation by physical medicine and rehabilitation physicians to assess eligibility for inpatient rehabilitation and other medical recommendations.

Postoperative neurological evaluation was performed immediately after surgery and on each subsequent day until discharge. A deficit was noted if a change from preoperative to postoperative neurological examination was documented prior to discharge. A deficit on follow-up was noted based on the patient's last clinical follow-up.

Analysis

Continuous and discrete variables are reported as means standard deviation and count (% total), respectively. The number of patients with persistent neurological changes who could be statistically analyzed was limited. Summary statistics were calculated using SPSS (V23.0, IBM).

Results

Table 1: Baseline characteristics and IONM findings for 50 patients with cervical myelopathy and IONM changes

Variable	Value
Age (years)	57.3 ± 15.3
Male	24 (48%)
Sex (male)	26 (52%)
Pathogenesis of myelopathy	
Degenerative	48 (96%)
Neoplastic	1 (2%)
Infection	1 (%)
Nurick grade	
1	25 (50%)
2	18 (36%)
3	5 (10%)
4	2 (4%)
Case time (hh:mm)	3:04 ± 1.08
IONM tech time (hh:mm)	4:28 ± 1.24
Length of stay (days)	3 ± 4
Follow-up time (months)	3.7 ± 2.4
Fusion approach	
Anterior	31 (62%)
Posterior	17 (34%)
Anterior & posterior	2 (4%)

Level of fusion	
Occiput	2 (4%)
C1	5 (10%)
C2	16 (32%)
C3	25 (50%)
C4	36 (72%)
C5	34 (68%)
C6	31 (62%)
C7	20 (40%)
T1	13 (26%)
T2	4 (8%)
Number of fusion levels	3.7 ± 1.8
Corpectomy	8 (16%)
Intraoperative neuromonitoring change	
EMG	30 (60%)
SSEP	16 (32%)
MEP	15 (30%)

The mean age was 57.3 ± 15.3 and 52% were females. 96% had degenerative pathology of myelopathy. According to Nurick grade, 50% were in grade 1.

Table 2: Sensitivity and specificity of IONM for predicting neurological deficits in CSM

	Deficits absent	Deficit present	Totals
Change in IONM	46	4	50
No change in IONM	90	5	95
Totals	136	9	145
	Value	95% CI lower limit	95% CI upper limit
Sensitivity	43.87	12.8	78.76
Specificity	69.52	58.52	77.43
Positive predictive value	8.16	1.85	21.56
Negative predictive value	96.52	89.27	97.53

Among the 50 patients with neuromonitoring changes, 4 patients showed postoperative neurological deficits. For the 90 patients without IONM changes, 5 patients showed some postoperative deficit that, although mostly mild, persisted up to last follow-up. Sensitivity of 43.87%, specificity of 69.52%, positive predictive value of 8.16%, and negative predictive value of 96.52% were identified for IONM in predicting postoperative neurological changes.

Discussion

Understanding the recovery of nerve function is the most urgent hope of spine surgeons. In the past clinical practice, clinicians mainly choose to arouse or conditioned reflex to judge the spinal cord injury and recovery level. In clinical practice, it is based on the physician's experience. The criteria for judging the level and the results of observation are not the same, and it is subjective. The imaging radiology technology developed in recent years has made up for the clinical judgment errors caused by the subjectivity of physicians to a certain extent. However, in recent years, somatosensory-evoked potential (SEP) is widely used by spine surgeons because of its high specificity to acute spinal cord and nerve injury. [19-21]

A total of 312 patients who had a diagnosis of degenerative myelopathy and whose case involved neuromonitoring were identified; 167 were excluded for various reasons, 50 patients showed an IONM change and 95 showed no IONM change. The mean age was 57.3 ± 15.3 and 52% were females. 96% had degenerative pathology of myelopathy. According to Nurick grade, 50% were in grade 1. Multiple guidelines, including those by the Joint Section of the AANS/CNS [22,24], position statements by the American Society of Neurophysiological Monitoring [18] and individual reviews/meta-analyses [23,25] have yielded conticting findings. Although good evidence supports the use of IONM to detect neurological changes, translating these findings to improvement of patient outcomes remains challenging. [24] Our current results show limited sensitivity for IONM in predicting postoperative recovery. Our study shows one method of using a multidisciplinary protocolized approach toward using IONM in patients with CSM.

Several recent meta-analyses have suggested that patient heterogeneity and IONM technique variation may account for the varying impact of IONM in reducing postoperative deficit. Thirumala et al [23] reviewed two studies that used IONM during CSM

surgery. The use of IONM was associated with a lower rate of worsening myelopathy or quadriplegia compared with studies where IONM was not used (0.91 vs. 2.71%). Variation in use of the Nurick scale, Japanese Orthopedic Association score or modified Medical Research Council muscle grading was seen among these studies, as well as a high interstudy heterogeneity index. C5 root and deltoid palsies were common among neurological deficits, with a rate of 4.56% (3.74% transient and 0.74% permanent) in patients without IONM compared with 0.84% rate in patients with IONM. Dysphagia was seen in 6.23% of patients without IONM and was not present in patients with IONM. Among the 50 patients with neuromonitoring changes, 4 patients showed postoperative neurological deficits. For the 90 patients without IONM changes, 5 patients showed some postoperative deficit that, although mostly mild, persisted up to last follow-up. Sensitivity of 43.87%, specificity of 69.52%, positive predictive value of 8.16%, and negative predictive value of 96.52% were identified for IONM in predicting postoperative neurological changes. Daniel et al [25] reviewed six studies in which IONM was used during spine surgery. Significant interstudy heterogeneity was noted. The pooled odds ratio of IONM to reduce postoperative deficit was not significant (0.1993; 95% CI: 0.0384, 1.035; p = 0.055). Limitations of studies evaluating IONM in CSM include the small sample size, occasional reliance on a single IONM modality (e.g., MEP), patient heterogeneity, and lack of comparison group. Lin et al [26] evaluated 152 patients with cervical compressive myelopathy and found that abnormal preoperative spinal cord T2 hyperintensity with T1 hypointensity was more likely in patients with IONM changes. The integration of imaging findings into preoperative stratification and prediction of outcomes in conjunction with IONM may be an interesting avenue of exploration in future studies.

Conclusion

Our study showed that IONM was efficacious as a surgical adjunct but showed limited accuracy in predicting postoperative outcome in contrast to some previous studies. Moreover, we describe how a standardized multidisciplinary collaboration using the best available evidence may serve as the most effective method to optimize patient care in light of the limitations and controversies of IONM.

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